Review of Air Dispersion Modelling of Methyl Bromide Fumigation Events

Prepared for

New Zealand Environmental Protection Authority

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Limitations:

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1.0 Introduction

Pattle Delamore Partners Limited (PDP) has been engaged by the New Zealand Environmental Protection Authority (EPA) to review and provide independent advice on an air dispersion modelling report prepared by Todoroski Air Sciences (TAS) which predicts the potential air quality effects of methyl bromide fumigations at the Port of Tauranga.

This report provides an outline of the findings our peer review of the *Air Dispersion Modelling – Methyl Bromide* prepared by TAS (the TAS Report), dated 16 September 2019. We note that this modelling assessment appears to have been commissioned at least in part in response to reviews of a previous modelling assessment undertaken by Sullivan Environmental Consulting (SEC, July 2018) and associated addendum (SEC, 2019), in which the reviews by TAS identified a number of issues that called the conclusions of the modelling assessment into question.

This report is limited to reviewing the information in the TAS Report, which we understand was commissioned to address the issues identified in the reviews of the SEC report and associated addendum.

1.1 Scope of the Review

The EPA have defined the scope of this review to include discussion and recommendations on:

- The suitability of the model(s) used in the report;
- The suitability of the parameter values used in the modelling;
- The validity of the conclusions in the report; and
- Other key issues relating to the report or modelling that the contractor considers important.

2.0 Background

In 2010, the EPA reassessed the continued use of methyl bromide as a quarantine and pre-shipment fumigant subject to controls. Decision HRC08002[1] set out that by October 2020, all applications of methyl bromide must be undertaken using recapture technology such that only 5ppm of methyl bromide exists in the headspace prior to venting.

[1] NZ EPA Environmental Risk Management Authority Decision, *Application for the Reassessment of a Hazardous Substance under Section 63 of the Hazardous Substances and New Organisms Act 1996, Name of substances: Methyl bromide and formulated substances containing methyl bromide, Application Number: HRC08002*, 28 October 2010.

Methyl bromide in its gaseous state is a colourless and volatile gas three time as dense as air. It is highly toxic at acute exposures and is readily absorbed through the lung and skin which can lead to chronic health effects with long term exposure. Methyl bromide gas is able to penetrate a variety of substances which allows its use as a pesticide and fumigant.

Stakeholders in Methyl Bromide Reduction (STIMBR) have applied to the EPA for a reassessment of Decision HRC08002 to allow the requirement for 5ppm of methyl bromide in the headspace prior to venting. STIMBR are seeking to have the current requirement replaced with a requirement to recapture of 80% of methyl bromide remaining at the end of fumigations.

As part of reassessment, STIMBR have arranged for air dispersion modelling assessments (Sullivan (2018) and Sullivan (2019)) to simulate the expected airborne concentrations of methyl bromide. Peer reviews of the modelling have identified issues with the modelling commissioned by STIMBR which likely result in underprediction of methyl bromide concentrations.

Consequently, the EPA has commissioned TAS to undertake an independent dispersion modelling assessment to assess the potential effects from methyl bromide fumigation at the Port of Tauranga. The following report presents our peer review of the TAS Report. In undertaking our review, we have considered the following reports:

- ASG (2019), Review of an Air Concentration Dispersion Modelling Assessment of Concentrations in Tauranga Port, New Zealand, prepared for Bay of Plenty Regional Council by Atmospheric Science Global (ASG), August 2019.
- Sullivan (2019), Addendum to Air Concentration Dispersion Modelling Assessment of Methyl Bromide Concentration in Tauranga Port, New Zealand, prepared for Stakeholders in Methyl Bromide Reduction by Sullivan Environmental Consulting (Sullivan), March 2019.
- Todoroski Air Sciences (TAS, 2019), *Air Quality Review Dispersion Modelling Assessment of Methyl Bromide*", prepared for New Zealand Environmental Protection Authority by Todoroski Air Sciences, September 2019.

3.0 Assessment Criteria

Assessment criteria need to be considered in order to assess the effects of concentrations of methyl bromide and should be set at a level below which human health effects are not expected to occur.

TAS identified the relevant assessment criteria for methyl bromide are:

- A 1-hour Tolerable Exposure Limit (TEL) of 1 ppm (3.9 mg/m^3);

- A 24-hour TEL of 0.333 ppm (1.3 mg/m^3);
- A chronic TEL of 0.0013ppm (0.005 mg/m^3); and,
- The New Zealand WorkSafe Exposure Standard as a Time Weighted Average (WES-TWA) of 5 ppm over an 8-hour period.

The TELs are designed to protect the public health from effects of exposure to methyl bromide and apply to areas where the public may be exposed. This means that in order to ensure health effects from exposure to methyl bromide do not occur, the concentration at and beyond the boundary of the Port of Tauranga should not exceed the TELs of 1 ppm and 0.333 ppm over 1-hour and 24-hours respectively.

The WES-TWA is meant to protect worker health and must not be exceeded at any location, including within the site boundary where fumigation occurs.

The modelling results presented in the TAS Report have been compared to the TEL, specifically to the 1-hour TEL as this has been identified as the main exposure risk from the fumigations.

PDP consider that TAS have identified the relevant assessment criteria and used them correctly in the modelling assessment.

4.0 Review of Modelling

4.1 Modelling Approach

4.1.1 Model Choice

The CALPUFF dispersion model was used to simulate the dispersion of methyl bromide discharges from a range of fumigation scenarios, and to predict the downwind concentrations of methyl bromide for assessment against the 1-hour TEL for methyl bromide.

CALPUFF is an advanced dispersion model which has been developed to deal with meteorological conditions that may occur in situations of complex terrain, low wind conditions, and coastal environments. The previous modelling report and associated addendum prepared by SEC used the comparatively simple dispersion model AERMOD, which does not consider these conditions.

Among the dispersion models which are currently in common use, we consider the use of CALPUFF to be the most appropriate considering the local terrain features, complex coastal environment, and occurrence of light winds at the Port of Tauranga.

The version of CALPUFF used in the TAS modelling has not been specified. There have been a number of updates of the CALPUFF model over the years. We would expect that the latest version of CALPUFF (Version 7) would ideally have been used, although our understanding is that the basic dispersion algorithms for point and volume sources has not significantly changed and so earlier versions would likely not have produced significantly different results for this assessment.

We note that methyl bromide is a dense gas relative to air, with a density of 4.0 kg/m^3, compared to a density of air of 1.3 kg/m^3 at standard temperature and pressure. Dispersion modelling of dense gases typically requires a specialised dense gas model to predict the behaviour of a denser than air gas. However given that the methyl bromide gas is diluted to a concentration of typically no more than 120 g/m^3 during fumigation (less than 3.2% by volume), and will become further dilute from mixing with air upon discharge to atmosphere, the resulting gas plume containing methyl bromide will not behave significantly differently from the surrounding atmosphere. We therefore consider CALPUFF to be an appropriate model for the methyl bromide fumigation discharges.

4.2 Meteorology

Meteorological data for use with CALPUFF was generated using the prognostic meteorological model TAPM, which was used to generate a 3D wind field for input into the CALMET diagnostic meteorological model. Observations of surface winds collected at the Tauranga airport meteorological station were incorporated into the TAPM model run. We have reviewed the methodology and input parameters for both TAPM and CALMET, which seem generally fit for purpose.

There is limited information in the TAS Report regarding how terrain and landuse were integrated into the CALMET run. CALMET requires a ‘geo.dat’ input file in order to adjust for terrain and land use effects as they vary throughout the modelling domain.

The TAS Report provides an evaluation of the modelled meteorological data in Appendix A of the report, which shows good correspondence of the CALMET-generated data used with CALPUFF, and the observed data at the Tauranga airport. The figures A-1 through A-5 of the TAS Report illustrate the surface layer of the 3D wind field, and indicate that the wind fields follow terrain well, and demonstrate that terrain effects have been incorporated into the model. PDP have not undertaken a quantitative analysis of the meteorological model performance but on this basis of the information provided we accept that the CALMET-generated data used in the modelling is of sufficiently good quality for this modelling assessment in terms of wind speed, direction, and temperature.

4.3 Modelling Scenarios

The modelling has considered methyl bromide releases from two types of log fumigation:

- From three log stacks covered with tarpaulins; and

- From a single ship with five hold containers at berth. (We note that the report states that the modelling has considered one or two vessels adjacent to each other berthed at the harbour. However, the model results as presented in the report only seem to be of a single ship scenario.)

Each of these types of fumigation were modelled assuming four different application concentrations of methyl bromide, which have been determined by requirements of treatment for export to various countries:

- 120 g/m^3 for 16 hours (China)
- 72 g/m^3 for 20 hours (India)
- 80 g/m^3 – not stated
- 40 g/m^2 for 16 hours (NZ)

The modelling also assumes five different recapture or recovery rates, from zero recovery up to a maximum of 95% recovery.

These scenarios will result in twenty different emission rates of methyl bromide for each of the two fumigation scenarios (4 application concentrations x 5 recovery percentages = 20 emission scenarios). However we note that the dispersion of the discharges itself will vary in direct proportion to the concentration of methyl bromide discharge, and so the predicted downwind concentrations of methyl bromide may be determined on a pro-rata basis (i.e. the model predictions for a single modelling base case run can be used to determine each of the 20 variations of initial application concentration vs percent recovery). TAS have not modelled each individual emission scenario, but pro-rated the results from a base case. PDP concur with this approach to assessing the impacts of each individual emission scenario.

4.4 Emissions Calculations

4.4.1 Emissions During Phases of Methyl Bromide Fumigation Process

TAS describe the fumigation process as consisting of four discrete stages, each of which require consideration in the modelling assessment, as summarised below:

4.4.1.1 Initial Application

Methyl bromide is applied to the fumigation area, either under the covered log stacks or within the ships holds. The amount of methyl bromide applied is dependent on the required concentration in g/m^3 and the volume of free air space within the ship holds or the log stacks. As methyl bromide loses some of its effectiveness as a fumigant under cooler temperatures, higher application rates are required in cooler temperatures, *i.e*. an extra 8 g/m^3 is applied for each

5 degrees below 21°C. The report states that fumigation is not undertaken at temperatures below 10°C.

The TAS Report states that the additional methyl bromide needed for cooler temperatures was added based on temperatures observed at the Tauranga Airport, however we have been unable to review the CALPUFF input files to verify these emission rates have been used.

The modelling makes assumptions as to the volume of free air space within the ship holds and log stacks. For the sheet enclosure of a log stack it is assumed there is a total volume of 1,200 m^3 (60 m x 5 m x 4 m) comprised of a log volume of 750 m^3 and volume of 450 m^3 of free air space. The modelling scenarios assume three log piles are fumigated simultaneously within a central part of the permissible fumigation areas of the Port of Tauranga. We note that a previous review of the SEL modelling undertaken by ASG (2019) questioned the use of a 450 m^3 free air space as not being particularly conservative and stated that the free air space could be significantly higher.

As a test of these free space assumption we have reviewed the annual monitoring reports submitted to the EPA by Port of Tauranga, which detail the number of fumigations and the amount of methyl bromide used on an annual basis. From these we calculated the average mass of methyl bromide used per fumigation. Assuming an application rate of 120 g/m^3, the PDP-calculated volume of free air within the log stacks is significantly greater than 450 m^3 assumed in the modelling. The average free air space for log stacks was calculated to be 689 m^3 for the 2012 to 2016 period, around 53% higher than what was modelled. Table 1 below provides the number of fumigations undertaken at the port, mass of methyl bromide used, and the estimation of free air space. The free air volume would be greater that detailed in Table 1 if the assumed concentration of methyl bromide is lower (*i.e.* if the applied concentration of methyl bromide is 80 mg/m^3, the average estimated volume of free air is 1034 m^3 per log stack fumigation).

Table 1: Log fumigations and methyl bromide use reported at Port of Tauranga, 2012-2016

Year	Number of log stack fumigations	Mass of methyl bromide used (kg)	Average mass of methyl bromide (kg/fumigation)	Estimated free air under within stacks (m^3)[1]
2012	3,073	205,241	67	557
2013	3,301	335,099	102	846

2014	2,104	160,001	76	634
2015	1,750	147,821	84	704
2016	2,169	183,926	85	707
Average	***2,479***	***206,418***	***83***	***689***

Notes:

1. *Assumption that methyl bromide is applied at a concentration of 120 g/m³ free air space*

The ships have been modelled as having 5 holds with individual dimensions of 24.5 m by 24.5 m with a depth of 15 m. This allows for a total volume of 45,000 m^3 across 5 holds per ship. The modelling has assumed a free air space of 3,800 m^3 per hold (19,000 m^3 per ship).

A similar assessment of fumigations of ship holds historically undertaken at Tauranga has been undertaken as presented in Table 2, showing the average free air space in the holds is closer to 5,000 m^3, around 30% higher than what has been modelled.

Table 2: Ship hold fumigations and methyl bromide use reported at Port of Tauranga, 2012-2016

Year	Number of ship holds fumigated	Mass of methyl bromide used (kg)	Average mass of methyl bromide (kg/fumigation)	Estimated free air under within stacks (m^3)[1]
2012	74	46,334	626	5,218
2013	120	72,129	601	5,009
2014	60	37,234	621	5,171
2015	32	17,705	553	4,611
2016	80	48,721	609	5,075
Average	***73***	***44,425***	***602***	***5,017***

Notes:

1. *Assumption that methyl bromide is applied at a concentration of 120 g/m³ free air space*

Overall we consider these assumptions of volume to be underestimated for both the log stacks and the for the ship holds, based on the annual fumigation reports provided to the EPA by the Port of Tauranga. It is also possible that the application of methyl bromide is in excess of the assumed maximum 120 mg/m^3 application concentration. Regardless, it would appear that the mass of methyl bromide used for a fumigation event is under-represented by the modelling assumptions in the TAS Report, which in turn will result in underpredictions of the ground level concentrations resulting from all stages of the modelling.

4.4.1.2 Fumigation Period

Once methyl bromide has been delivered to the ships holds or log stacks, a designated fumigation period is required to allow the methyl bromide to penetrate the timber. There are varying requirements ranging from 16 (for export to China) to 20 (for export to India) or more hours. The modelling has assumed a 24-hour fumigation period for all scenarios.

There is potential for fugitive releases of methyl bromide during this period in the event that the sheeting or ship holds are improperly sealed. It was assumed that 10% of the fumigant is released gradually from the sources over the 24-hour fumigation period.

Although not explicitly stated in the TAS report, we have implied that the 10% loss of fumigant through fugitive means is not subtracted from the release of fumigant during the subsequent ventilation and desorption stages. Assuming this is correct, this assumption provides an element of conservatism when calculating the 24-hour average concentrations of methyl bromide resulting from the fumigation.

4.4.1.3 Ventilation

After the 24-hour fumigation period, the sheeting covering the log stacks is removed, and the doors to the ships holds are opened, allowing the residual methyl bromide to escape. If recapture of methyl bromide is undertaken, it will occur prior to the ventilation stage.

Ventilation of log stacks is assumed to occur over a 10-minute period. It is not clear from the TAS Report if the modelling assumes all three log stacks are assumed to be ventilated during the same ten-minute period, or if they are ventilated in series. However, since CALPUFF as normally used only considers time steps of one-hour, this may be a moot point. Without having access to further information, we would assume that the ventilation of all three log stacks were modelled to occur during the same hour. In this case, the ventilation period of the log stacks is effectively a one-hour event for the purpose of modelling. We note that the Version 6 and Version 7 of CALPUFF have the ability to model sub-hourly discharge events which might be appropriate for modelling these types of release, although this is dependent on development of sub-hourly meteorological files for which observational data may not be available.

Ventilation of ship holds have been modelled over a six-hour period, with the emission rate varying over this period. The emission rates are dependent on the assumed free air space in the hold and the initial application concentration. The emission increase over the first two hours, then decrease over the next four hours. The report does not say how these variable emission rates were determined. However, given the location of logs within the ship holds and the limited air exchange between the holds and outside atmosphere TAS's assumption on the ventilation of ship holds appears to be sensible to PDP.

As discussed previously the ventilation discharges are likely underestimated as they are based on assumptions of free air space in the ship holds and methyl bromide application rates that appear to be incorrect based on records of ship hold fumigation reported by the Port of Tauranga.

The ventilation stage makes up the bulk of the methyl bromide discharged from the fumigation process and also occurs over the shortest time period, and so is the primary source of concern in terms of risk of exceeding the TELs, particularly for acute effects.

This potential uncertainty in the amount of methyl bromide discharged from the fumigation processes emphasises the importance of the model validation discussed in Section 4.6.1.

4.4.1.4 Desorption

During the fumigation process approximately 50% of the methyl bromide applied is assumed to be absorbed by the timber. After the ventilation period the absorbed methyl bromide desorbs gradually over time. The rate of desorption has been modelled by TAS per the exponential decay model presented in *Sorption and desorption characteristics of methyl bromide during and after fumigation of pine (Pinus radiata D. Don) logs* (Hall et al, 2016).

The initial concentration of methyl bromide determines the initial emission rate of desorption which reduces rapidly. The bulk of methyl bromide is desorbed after four hours, although the modelling considers desorption for 24 hours after ventilation. The TAS Report does not explicitly state what percentage of methyl bromide is assumed to have been absorbed by the wood for the purpose of determining the desorption emission rates. However, the TAS Report does state that a retention rate of 50% of the original concentration was used to calculate the amount of methyl bromide remaining following the fumigation period, which we assume to mean the other 50% is desorbed over the next 24 hours. TAS's assumption on the desorption rate appears to be sensible to PDP, however it would be helpful to see the references which this assumption is based.

4.4.1.5 Modelling of Overall Fumigation Cycle

Based on the fumigation phases described above, we understand that each fumigation event begins with an initial 24-hour period in which the only emissions are fugitive emissions from the ship holds or log stacks. At the end of this period, the ventilation of the non-absorbed methyl bromide contained in the free air space is discharged over a 1-hour (log stacks) or 6-hour (for ship hold) period. This is followed by another 24-hour period in which the absorbed methyl bromide is desorbed from the logs.

The TAS Report states that in order to capture the worst case dispersion conditions during the highest emission periods, "The fumigation and emission for either three log stacks or a ship was modelled for any hour by separately modelling a ship or three log piles for each hour of the day." In this way the peak emission events (i.e. the ventilation periods) would be assessed at each hour of the day. It is not clear from the report how this has been accomplished, given the fumigation cycles last for at least two full days (including the fugitive emission phase, ventilation phase, and desorption phase) and this should be clarified.

4.4.1.6 Summary

Table 3 summarises the emission scenarios and assumptions used in determining emission rates. We agree in general with the assumptions used in the emissions determination with the exception of the free air space used to calculate the initial mass of methyl bromide applied. As discussed, the mass of methyl bromide used in the fumigations appears to have been underestimated when compared to actual use data reported by the Port of Tauranga, in which case the modelled concentrations will be under-predicted for all stages of fumigation.

Table 3: Emission calculations and assumptions used for dispersion model

Scenario	Description	Assumptions
Initial application rate	Application concentrations of methyl bromide as required for export	40 g/m^3, 72 g/m^3, 80 g/m^3, and 120 g/m^3. The mass of methyl bromide is determined by assumptions of 450 m^3 free air space for log stack fumigation and 3,850 m^3 for ship hold fumigation. An extra 8 g/m^3 of methyl bromide is added for every 5 degrees below 21°C.

Fumigation	Fugitive emissions of methyl bromide from the sheet enclosures and the ship hold containers during a 24-hour fumigation period.	Assumption that 10% of total methyl bromide applied escapes throughout the 24-hour fumigation period.
Ventilation	The ventilation period (following the fumigation) when the sheet enclosures are lifted and the ship hold doors are opened.	All scenarios: Assumption that 50% of the initially applied methyl bromide remains after absorption into treated timber. Assumption of variable recapture rates of methyl bromide of 0%, 50%, 75%, 80%, and 90%.
		Log stacks: Release of residual methyl bromide from free air space in the log stacks over a 10-minute period at a constant rate.
		Ship hold: Release of residual Methyl bromide from free air space in the holds over a six-hour period at a variable rate.
Desorption	Desorption of Methyl bromide from treated timber over a 24-hour period.	Emission rates calculated by empirically-determined relationship between the initial application concentration and an exponential decay curve over a 24-hour period.
General modelling approach	All Scenarios	Each modelling scenario occurs over a 24-hour period of fugitive emissions followed by either a 1-hour (log stacks) or 6-hour (ship holds), followed by a 24-hour desorption period. Multiple model runs were undertaken to capture fumigation events through each hour of one 24-hour period, though it is not clear from the report how this was accomplished.

4.5 Model Configuration

The document states that the model was set up in general accordance with the *Generic Guidance and Optimum Model Setting for the CALPUFF Modelling System for Inclusion in the 'Approved Methods for the Modelling and Assessments of Air Pollutants in NSW, Australia (*TRC, 2011*).*

We have not been provided the CALPUFF input files to enable us to verify what model settings have been used, but we do accept that the recommendations in the NSW guidance document to represent current best practice for setting up the CALPUFF model.

4.5.1 Source Parameterisation

Fugitive emissions from both the ship holds and the log stacks have been modelled as volume sources. The log stacks were also modelled as volume sources during the ventilation period. The parameterisation of the volume sources appear to conform to recommendations in the MfE's Good Practice Guide for Dispersion Modelling (2016), which recommends using one quarter of the height and width of a volume source to determine the initial horizontal and vertical spreads from both the ship holds and log piles.

For the ventilation phase, the ship holds have been modelled as a point source. Point sources in dispersion modelling are typically used for stack discharges, which are physically quite different from the ship hold discharges. The TAS Report does not state the reasoning for using a point source, but we would expect the reason to be so that the effects of building downwash from the ship's structure could be incorporated into the model. We consider this approach to be a reasonable way to consider the potentially significant downwash effects resulting from the structure of the ship. However, given the wide area of the ship holds and slow discharge rate of air from them, treating this discharge as an area source may have been appropriate. It would have been helpful for TAS to consider and discuss the impacts of source type choice on the model results.

The TAS Report does not state how the desorption phase of the fumigation has been modelled. Presumably the ship holds and log stacks would also have been modelled as volume sources during the desorption phase.

4.5.2 Model configuration

Other elements of the model inputs which were not included in the TAS Report, but we consider necessary for a complete review include:

- Any non-standard model settings and dispersion parameters that may have been used.
- Whether building downwash effects were considered for the ship hold ventilation, and what the dimensions of the ship were.

- Spacing of the receptor grid

4.6 Model Results

4.6.1 Model Validation

There is limited monitoring data available to validate the modelling predictions. Both the TAS Report and the ASG (2019) review of the Sullivan (2019) report cite two monitoring events that occurred at the Port of Tauranga during a ship hold fumigation events. These two monitoring events occurred on 1 August 2018 and on 22 August 2019. During both of these monitoring events, methyl bromide was measured as 1-hour average concentrations 300 to 600 metres downwind of the ship hold fumigations at concentrations of between 1 and 4 ppm (3,900 to 15,200 µg/m^3). The TAS Report provides an isopleth diagram in Figure 4-1 of the report which shows 1-hour average contours at the 3,900 and 15,200 µg/m^3 concentrations, for the various ship hold modelling scenarios. The contours roughly indicate that the distances from the fumigation where the 1-hour TEL (3,900 µg/m^3) is predicted to be exceeded are between 700 metres (for a 40 g/m^3 application concentration to 1.6 kilometres (for the 120 g/m^3 application). However, the contour plots show the worst-case predictions of the model, being the highest predicted 1-hour concentrations over a five-year period and do not necessarily relate to the conditions occurring during the actual monitoring events. The comparison of the monitoring and modelling results suggests that the modelling is conservative.

The TAS Report also presents a comparison of model results of a ship hold ventilation during the 1 August 2018 monitoring event, and states that the model run which assumed a 120 g/m^3 application of methyl bromide showed close agreement with the monitoring results of 4.3 ppm and 3.3 ppm ENE of the ship for the same times and locations. There are still a number of unknown factors, particularly regarding the mass of methyl bromide which would have been released during this period. However, we agree that the model can be said to represent reasonably well the likely actual case of the ship hold fumigation event monitored. PDP note that this result indicates the model may be performing reasonably well for this single event, but we do not consider this a full or robust model validation.

We note that the annual monitoring methyl bromide fumigation reports provided by the Port of Tauranga to the EPA include the results of monitoring that is required to take place at the at the boundary of the buffer zone for every fumigation event. The buffer zone boundary is required to be a minimum of 100 metres from the fumigation area, although it may be greater than this. All of the reports reviewed state that no methyl bromide was detected at any time. This is clearly in contrast to what the modelling is indicating and again suggests the model results are conservative.

4.6.2 Highest Predicted 1-hour Average Ground Level Concentrations

The model output data files were not available for review. PDP have not been able to check that the reported data matches those in the model output file.

The modelling presents the results of the highest predicted 1-hour average concentrations for each of the modelling scenarios. The TAS Report only presents the results of the 1-hour average concentration predictions. Isopleths diagrams showing the 3,900 µg/m^3 contour lines where the 1-hour average TEL is exceeded are included in the report. We note that the isopleth plots show the highest 1-hour average concentration that may occur over the five-year modelling period, and so in this respect is highly conservative as it is unlikely that the ventilation releases would occur during the worst-case meteorological conditions.

Isopleth diagrams in Figure 4-2 of the TAS Report presents the model results of log stack ventilation with the initial application of 120 g/m3 of methyl bromide. The diagram shows the maximum 1-hour contours at the TEL of 3,900 µg/m^3 for varying capture rates, from 0% up to 90% capture. The contour plots indicate that the TEL may be exceeded up to a distance of one kilometre from the ventilation with no recapture. This distance reduces to, roughly, 400 metres with 50% recapture and 200 metres with 80% capture. The 80% capture, for this particular location, appears to restrict the modelled area of TEL exceedances to within the Port Area. However, we note that if the fumigation were to occur closer to the site boundary than has been modelled, there could still be offsite exceedances.

Figure 4-3 provides a similar diagram for the ship hold ventilation scenario. With no recapture, the TEL is predicted to be exceeded within a distance of approximately 2.1 kilometres. This reduces to roughly 1.6 kilometres with 50% recapture and 1.4 kilometres with 80% capture. The area of TEL exceedance extends far offsite in this scenario, even with a recapture rate of up to 90%.

Given the information available in the report, PDP consider that the results presented by TAS appear to reflect the modelling undertaken. However, the limited validation (Section4.6.1) suggests the modelling may well be conservative.

4.6.3 Other time averaging periods

We note that the TAS Report has not considered other averaging periods, specifically the 24-hour TEL of 0.333 ppm (1.3 mg/m^3) and the chronic TEL of 0.0013ppm (0.005 mg/m^3).

4.6.4 Seasonal and Diurnal Analyses

The TAS Report presents further analysis of the 1-hour modelling results to determine the differences in model predictions at different times of the year and different times of the day. As the analysis is of 1-hour averages, we can assume that only the ventilation of the log stacks and ships holds is considered, but this is not stated in the TAS report

The differences in model predictions would, in the main, be due to differences in meteorology seasonally and diurnally. The only other parameter that would change is if additional methyl bromide has been assumed to be added to the fumigations during cooler temperatures (*i.e.* between 10°C and 20°C).

Figure 4-4 of the TAS Report shows time-series graphs of the log stack fumigation scenario (with a 120 g/m^3 application concentration and with 80% recapture). The plots show the predicted concentrations for different hours of the day over the five-year modelling period. Overall, the plots show a trend for higher concentrations during winter months, which is likely due to a combination of poorer dispersion conditions and also the need for additional application of methyl bromide during cooler weather, if indeed this is included in the modelled emissions. The highest concentrations, with the greatest number of TEL exceedances at a distance of 50 metres, are predicted to occur between 4pm and 4am, with the lowest concentrations being predicted between 8am and 4pm.

Figure 4-6 of the report shows the same data but presented as the highest percentile values for each hour over a 24-hour period. The shows a strong diurnal profile of predicted concentrations at 50 metres from the source, with a marked decrease in concentrations between the hours of 8am and 3pm. This can most likely be attributed to the improved dispersion that occurs during daylight hours. This plot also shows the various percentile levels, from the 95th percentile up to the 100th percentile, and shows similar results from the 98th to the 100th percentile predictions at 50 metres.

PDP consider these results sensible as the dispersive power of the atmosphere is greater during daylight hours than at night.

4.6.5 Applicability of Model Results to Other Ports

The TAS Report provides a discussion of the potential applicability of the modelling undertaken for the Port of Tauranga to other New Zealand ports, namely Northport and Napier Port. TAS consider both ports have similar meteorological and climactic conditions, conclude that provided the nature and scale of fumigations undertaken at the different ports are similar, that the modelling results can be used as a rough approximation to gauge the potential impacts of the fumigations by distance from the source.

Apart from the source configuration, which we expect would be the same for other locations as has been assessed in the TAS Report for Tauranga, the main input parameter which would affect the downwind concentrations in the near field is the mass emission rate of methyl bromide. The emission scenarios covered in the Port of Tauranga modelling should reflect those occurring at other ports.

As a first approximation PDP would agree with TAS' conclusion the model results have some applicability to other ports. However, PDP suggest that this transfer of results from one location to another must be considered with due caution, especially if the receiving environment is more sensitive than at the Port of Tauranga.

5.0 Discussion and Conclusion

In our review of the TAS 2019 modelling report, subject to the information made available, we have found that the modelling for the most part was fit for purpose in terms of selection of model, selection of modelling parameters, development of meteorological data, and configuration of the emission sources. The main issue which would affect the modelling results is that the estimation of methyl bromide used on a per fumigation basis appears to be underestimated when compared to historical usage as reported by Port of Tauranga.

The mass emission rate of methyl bromide used in the modelling has been calculated based on assumed application concentrations ranging from 40 mg/m^3 to 120 mg/m^3 and estimates of free air space within the fumigation spaces of 450 m^3 for log stacks and 3,850 m^3 for a ship hold. Based on a comparison with historical fumigation events at the Port of Tauranga, it appears that these assumptions result in an underestimation of the actual amount of methyl bromide released per fumigation.

For future modelling studies we would recommend obtaining data from the port fumigation to determine a more realistic application rate of methyl bromide for the various fumigation scenarios and at various application concentrations. Determining methyl bromide emissions on a mass balance basis would be more accurate than using theoretical volumes and concentrations based on unknown factors such as free air space in the fumigation spaces.

Based on the discrepancy between the compliance monitoring as reported in the annual reports to the EPA and the model predictions which indicate that methyl bromide would likely be at detectable levels, we consider a more robust validation of the model results with monitoring data to be a key data gap. We understand that there have been previous modelling and monitoring validation studies undertaken by Crown Research Institutes in New Zealand. These were outside the scope of the PDP review but could add value in regard to confirming the choice of model, input values and validation.

Although of less concern, we also note the following issues:

- The modelling report only considered one fumigation event at once, whereas it could be possible that multiple events could be occurring simultaneously. For example, logs there could be a ventilation release from log stacks at the same time that fumigated logs are desorbing from ship holds. Based on the number of fumigations historically undertaken at the Port of Tauranga, as presented in Table 1 and Table 2, there would be multiple fumigations of log stacks for most days of operation, although there have been comparatively fewer ship hold fumigations.

- The modelling report states that two ships have been modelled as simultaneously releasing, but only the single-ship scenario has been presented.
- Only one-hour averages have been presented for comparison against the acute TEL of 1 ppm. This would capture the ventilation phase of the fumigations, but not the fugitive emissions or desorption phase. We recommend that the 24-hour and annual average concentrations of methyl bromide also be considered, particularly as there are residential areas nearby which may be impacted by longer term exposure.
- The log stack ventilations occur over a ten-minute period but have presumably been modelled over an hour. We recommend investigating the feasibility to model sub-hourly emissions, and modelling as such if practicable.
- For a complete review we would recommend reviewing that the model configuration and results be confirmed by inspection of the review of the input and output files. These files were not available for the current review.

Aside from the issues raised above, we consider the modelling as presented in the TAS Report to conform to good modelling practice.

6.0 References

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